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Discriminating "top-heavy" versus "bottom-heavy" geometric patterns in 2- to 4.5-month-old infants

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ABSTRACT

Simion, Valenza, Macchi Cassia, Turati, and Umiltà (2002) suggested that newborns preferred "top-heavy" stimuli and such bias may account for neonatal face preference. However, convergent evidence for the discriminability between the top-heavy versus bottom-heavy patterns has not been demonstrated. We used a modified familiarization/novelty procedure (Chien, Palmer, & Teller, 2003) to assess basic discriminability between "top-heavy" and "bottom-heavy" geometric patterns in 2- to 4.5-month-old infants. Each infant was tested with three types of top-heavy and bottom-heavy geometric figures and received both familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions. If infants of this age can discriminate the two configurations and there is no intrinsic bias toward either pattern, we expected to see significant and about equal novelty effects in both familiarization conditions. If there is a strong intrinsic bias for the top-heavy configuration, we expect to see a greater preference for the top-heavy patterns in the familiarization-to-bottom-heavy condition. Our results ($N = 24$) showed significant and equal novelty preferences in both familiarization conditions across age and figure types, suggesting a reliable discriminability between top-heavy and bottom-heavy configurations and there is no intrinsic bias towards either configuration at this age.

1. Introduction

One fundamental issue in cognitive neuroscience is how information of specific domains is processed in the human brain. In light of this, face processing is one of the most interesting topics because humans are excellent face "processors" (e.g., identity, emotion, sex, age, intention, etc.). Several lines of evidence proposed that face processing in adults rest on an anatomical and/or a functional specialization of brain circuits (e.g., Farah, 2000; Farah, Rabinowitz, Quinn, & Liu, 2000; Kanwisher, 2000; c.f., Gauthier & Logothetis, 2000). How the expert-like face-processing capacity takes place in the life span and what determines its functional specialization have been hotly debated issues since the late 80 s. Despite the fact that human neonates' vision is very limited at birth and improves substantially during the first year of life (Atkinson, 1984; Teller, 1997), the observation that newborns display visual preference for human faces (Bushnell, Sai, & Mullin, 1989) or face-like figures (Goren, Sarty, & Wu, 1975) has been taken as the rock-solid proof of existence of a *domain-specific innate bias* toward this class of stimuli (e.g., de Schonen & Mathivet, 1989; Johnson & Morton, 1991).

But there is a different voice. Recently, Simion, Macchi Cassia, Turati, and Valenza (2001) demonstrated that newborns showed a looking preference for non-face geometric patterns that had more elements in the upper part (i.e., "top-heavy" configuration) as opposed to those had more elements in the lower part (i.e., "bottom-heavy" configuration). In addition, by systematically manipulating locations of the three black squares in a paddle face to maintain facedness and/or up-down asymmetry, Turati, Simion, Milani, and Umilta (2002) cleverly demonstrated that it was not the degree of facedness, but the up-down asymmetry in a pattern that was crucial in determining newborn's face preference. Undoubtedly, the structure of a face is up-down asymmetrical (i.e., two eyes in the upper and one mouth in the lower part), thus, some researchers have proclaimed that neonatal face preference may actually reflects a *non-specific* perceptual preference for up–down asymmetry (i.e., a bias towards top-heavy patterns), rather than an innate bias for face-specific representation (Simion, Macchi Cassia, Turati, & Valenza, 2003; Simion et al., 2001, 2002; Turati et al., 2002; Macchi Cassia, Turati, & Simion, 2004; Turati, 2004).

The hypothesis that a preexisting non-specific perceptual bias for top-heavy configuration may explain neonatal face preference is truly original and logically simplistic. Nevertheless, several deeper issues deserve further investigation. The first question is about

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the developmental trajectory. How long will such a non-specific structural bias stay in infancy? Is it a long-lasting effect or a short-lived phenomenon only present at birth? The second question is about the strength of the bias. How strong is the top-heavy bias? Is it as strong as a reflex (i.e., a fixed behavior) or can it be eliminated or enhanced via operant conditioning? The third question is about the physiological basis. What kinds of visual neural substrates in a newborn infant's brain are responsible for such an up-down asymmetry bias? Perhaps the last question is the hardest one among the three; nevertheless, the first two questions can be empirically addressed (Chien, Hsu, & Su, 2009).

Up-to-date, few studies have explored the question regarding whether the "top-heavy" configuration bias is still present at 3 or 4 months of age (Islam, Lobue, & DeLoache, 2010; Quinn, Tanaka, Lee, Pascalis, & Slater, 2010; Turati, Valenza, Leo, & Simion, 2005). Using an eye-tracker apparatus, Turati et al. (2005) systematically investigated the face preference phenomenon and its underlying mechanisms at 3 months of age. The results of Experiment 1 showed that 3-month olds preferred natural face images to unnatural ones, replicating and extending previous evidence obtained with schematic face-like stimuli. However in Experiment 2, when viewing non-face like "top-heavy" versus "bottom-heavy" geometric patterns (Groups 1 and 2, p. 264), 3-month-old infants did not show consistent preference for the top-heavy patterns. More specifically, when infants were shown pairs of top-heavy versus bottom-heavy T-shaped patterns (Group 1), their visual preference for the top-heavy ones disappeared, which was radically different from that exhibited by newborns (Simion et al., 2002). However, when the other type of stimuli with four elements in the upper or lower half of the configuration (Group 2) was tested, 3-month-old infants showed a clear preference for the top-heavy configuration over the bottom-heavy one, which paralleled the findings with newborns (Simion et al., 2002). Thus, Turati et al. (2005) made a conclusion that "a possible interpretation of these outcomes might suggest that, at 3 months of age, the general mechanism responsible for infants' visual preference for top-heavy patterns is still present but weaker and, thus, is activated only when up–down asymmetry is highly salient. Following this line of reasoning, the stimulus with four grouped elements in the upper half would still be able to activate the up–down asymmetry detector. In contrast, the top-heavy T shape that has only three elements in the upper half would no longer be able to trigger a preferential response. In this view, preference for up–down asymmetrical patterns would not disappear abruptly but rather would do so progressively during the first months of life" (pp. 269–270).

Based on the above findings, it remains unclear to us whether the strength of "top-heavy" bias in 3-month olds is genuinely correlated with the salience of "top-heaviness" of the stimuli because only two types of configurations were used in Turati et al. (2005). Secondly, a lack of looking preference can be owing to a lack of discriminability between the top-heavy and the bottom-heavy geometric patterns. This possibility has not been fully ruled out. Therefore, the overarching goal of the present study was to test the basic discriminability of the three types of top-heavy versus bottom-heavy geometric patterns used in Simion et al. (2002) with a modified familiarization/novelty preference procedure and in infants with a wider age range (between 2 and 4.5 months).

The test stimuli included 3-(T-shape), 4-(甲-shape), and 5-(⊓-shape) grouped elements on the top half of the configuration and each infant will view all three types of geometric figures (i.e., a within-subject design). According to Simion et al. (2001), the difference among the three types of stimuli was the number of elements placed in the upper versus the lower part of the configuration (i.e. 3, 4, or 5 elements). That is, the one with only three elements (i.e., T-shape) on the upper part has a "weaker" top-heaviness than the ones with four or five elements (i.e., 甲-shape, and ⊓-shape). If the salience of top-heaviness is positively correlated with the strength of the 'top-heavy' configuration bias (say, ⊓-shape > T-shape) as suggested by Turati et al. (2005), we would expect to find differential results among the three types of geometric patterns. On the contrary, if the top-heavy configuration bias has vanished at 3 months of age regardless of the salience of up-down asymmetry in a figure, we expect to see no difference in the results among all types of figures.

2. Using FNP procedure to assess novelty preference and intrinsic preference

We assessed infants' novelty preference as well as intrinsic preference for the "top-heavy" versus "bottom-heavy" figures with a multiple discrete-trial familiarization technique termed the forced-choice novelty preference (FNP) procedure (Chien, 2003; Chien et al., 2003; c.f., Civan, Teller, & Palmer, 2005). The forced-choice novelty preference procedure is a hybrid technique that combined the familiarization/novelty preference paradigm (Fagan, 1970) with the forced-choice preferential-looking procedure (Teller, 1979). Each FNP trial contains a study and a test phase, in which two identical geometric figures (either "top-heavy" or "bottom-heavy" patterns) will be presented side-by-side for several seconds (the study phase), followed by two test stimuli where one is the same as in the familiarization and the other is a novel one that was rotated 180° (the test phase). Because young infants are known to have novelty preferences (Hunter & Ames, 1988), we expected that infants would consistently look more at the novel stimulus than at the familiar stimulus. The observer was blind to the location of the novel stimulus, which was randomized across trials. To complete the test phase of a particular trial, the blind observer integrate all possible infant looking cues (e.g., the first fixation, duration and number of looks on each side) and makes the best 2-alternative-forced-choice judgments about the location of the novel stimulus in the test display (i.e. left or right). Fig. 1 illustrates some of the sample trials in the present study. Note that each infant received both the "familiarized-to-top-heavy" and "familiarized-to-bottom-heavy" conditions.

Let us take the T-shape figures for example to illustrate the interplay between novelty preference, discriminability, and intrinsic preference (see Fig. 1: Trial #1 in Panel A and Trial #2 in Panel B). Suppose the probability for an individual infant being judged to prefer the upright T-shape figure (which is the novel stimulus) in the *familiarized-to-bottom-heavy* condition is as follows (see Fig. 1: Panel B Trial #2):

$$\begin{aligned}&\mathrm{OPC}(\text{upright T-shape}, \text{bottom-heavy})\\ &\quad = \mathrm{NP}(\text{difference between upright T-shape and inverted T-shape})\\ &\qquad + \mathrm{IP}(\text{upright T-shape})\\ &\qquad - \mathrm{OE}(\text{observer's experience}, \text{individual infant's looking factors})\end{aligned} \tag{1}$$

where OPC = observer's percent correct, the first symbols in the parenthesis indicates the probability for the observer correctly judging the location of the upright T-shape over repeated trials, and the second symbol representing the familiarization condition in this case is familiarized-to-bottom-heavy condition; NP = novelty preference, which should be a function of the discriminability between the upright and the inverted T-shape figures; and IP = intrinsic preference, which indicates the strength of the intrinsic preference/bias for upright T-shape unaffected by prior familiarization. The last term OE = observer's error, which represents the collective influences of the infant's idiosyncratic responsiveness and observer's experience in FNP judgments that may undermine the true score of OPC.

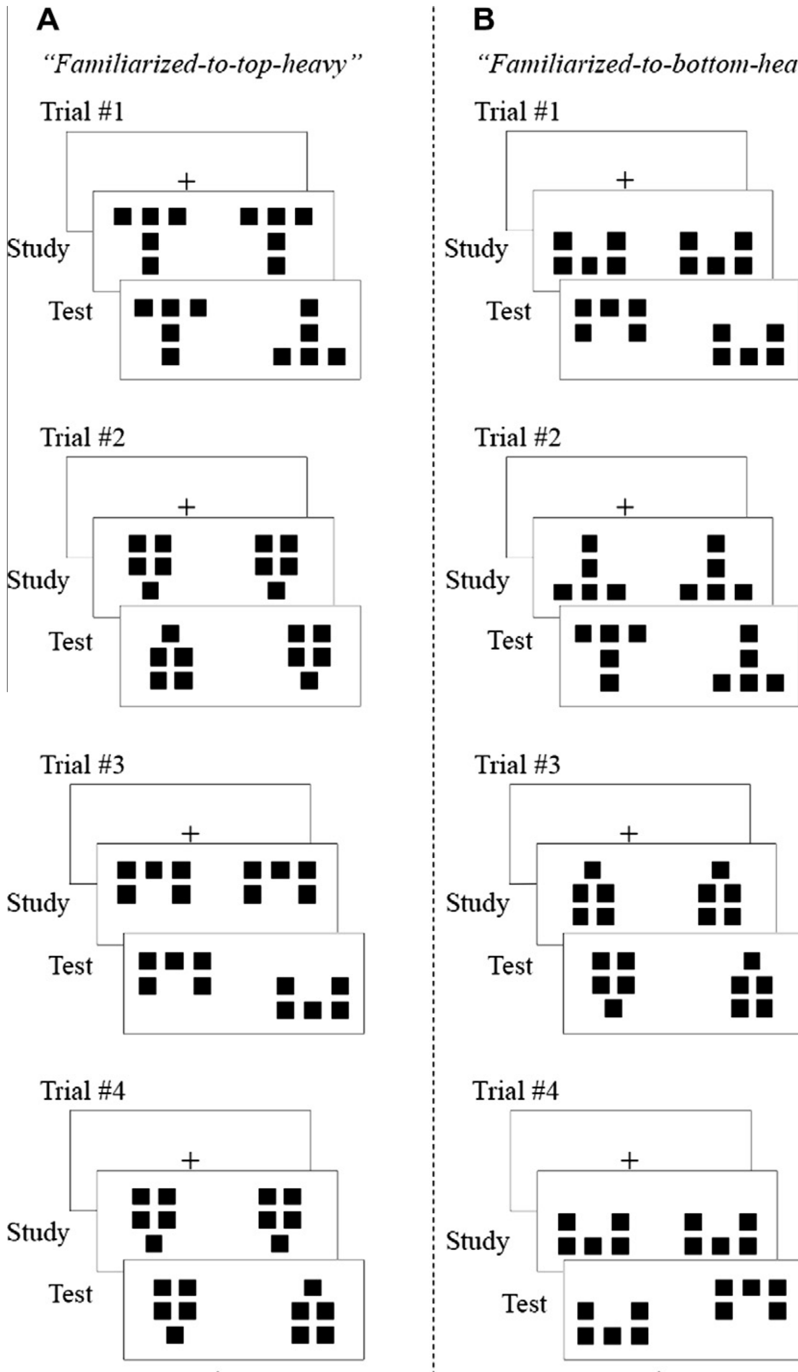

Fig. 1. The three pairs of "top-heavy" and "bottom-heavy" geometric patterns used in the study that are adopted from Simion et al. (2001). Panel (A) shows the familiarized-to-top-heavy geometric patterns condition. Panel (B) shows the familiarized-to-bottom-heavy geometric patterns condition. Each FNP trial has two phases: a study phase and a test phase. In the test phase, the observer judges which stimulus that the infant prefers and makes a forced-choice response about the location of the novel stimulus. Because young infants are known to have novelty preferences, if the differences between the familiar and the novel stimuli are discriminable, we expect that infants would consistently look more at the novel stimulus than at the familiar stimulus. The observer is blind to the location of the novel stimulus, which was randomized across trials.

Let us then consider the probability for the same infant being judged to prefer the inverted T-shape figure (which is the novel stimulus) in the *familiarized-to-top-heavy* condition by the same observer (see Fig. 1: Panel A Trial #1):

$$\begin{aligned}&\mathrm{OPC}(\text{inverted T-shape}, \text{top-heavy})\\&= \mathrm{NP}(\text{difference between inverted T-shape and upright T-shape})\\&\quad + \mathrm{IP}(\text{inverted T-shape})\\&\quad - \mathrm{OE}(\text{observer's experience and individual infant's looking factors})\end{aligned} \tag{2}$$

Again, OPC = observer's percent correct, the first symbols in the parenthesis indicates the probability for the observer correctly judging the location of the inverted T-shape over repeated trials, and the second symbols representing the familiarization condition in this case is familiarized-to-top-heavy condition; NP = novelty preference, which should be a function of the discriminability between the upright and the inverted T-shape figures. Note that in this case the perceptual difference between the top-heavy and the bottom-heavy T-shape figures is identical to the previous condition, and hence the discriminability shall be identical as well. IP = intrinsic preference, which indicates the strength of the intrinsic preference/bias for inverted T-shape in this case. Finally, as in this case the same infant and observer are involved, the term OE shall be very similar to that in the previous condition. Thus, given the same stimulus pair in the test phase, the same infant participant, and the same observer when we compare Eqs. (1) and (2), it follows that IP is the only term that may differ in the two familiarization conditions. Going back to our original concern regarding the strength of the intrinsic top-heavy configuration bias, if the intrinsic "top-heavy" configuration bias is strong and still present in the infants (i.e. *IP (upright T-shape) > 0*), this will favor a higher value of OPC for correctly judging the location of the upright T-shape figure in the familiarized-to-bottom-heavy condition. In contrast, if there is no intrinsic bias for either the "top-heavy" or "bottom-heavy" configuration (i.e., *IP(upright T-shape) = IP(inverted T-shape) = 0*), the observer's percent correct scores (OPC) for the two familiarization conditions shall not be different at all.

Taken together, the present study aimed to evaluate the following hypotheses with the FNP technique. First of all, if infants of this age range can readily discriminate the differences between top-heavy and bottom-heavy configurations, we expect to obtain greater-than-chance OPC (significant novelty preferences) for all three types of figures across familiarization conditions. Secondly, if the salience of top-heaviness is positively correlated with the strength of the 'top-heavy" configuration bias (i.e., ⊓-shape > 甲-shape > T-shape) as suggested by Turati et al. (2005), we would expect to find the following pattern of results: In the *familiarized-to-bottom-heavy* condition, the OPC for the top-heavy ⊓-shape figure shall be the highest, followed by that for the 甲-shape figure, and the OPC for T-shape figure shall be the lowest among the three. The reversed pattern shall be found in the *familiarized-to-top-heavy* condition. Namely, the OPC for the bottom-heavy ⊓-shape figure shall be the lowest (owing to a stronger intrinsic bias for the top-heavy figures that canceled out novelty preference for the bottom-heavy figures), followed by that for the 甲-shape figure, and the OPC for bottom-heavy T-shape figure shall be the highest among the three. However on the contrary, if the top-heavy configuration bias has vanished at this age regardless of the salience of up-down asymmetry in a figure, we would not find any significant differences in the OPC scores across figure types and familiarization conditions.

3. Material and methods

3.1. Participants

Thirty healthy, full-term infants aged between 2 and 4.5 months were recruited from the Taichung Metropolitan areas. Most of the parents joined our study by means of advertisements made through China Medical University Hospital, the university, and/or through the parenting community group on the Internet. They were assigned to three age groups: $\leqslant$13 wks (mean = 10.2 wks), 13–18 wks (mean = 14.8 wks), and 18–23 wks (mean = 19.2 wks). All infants were born within ± 14 days of their due dates, and had no history of blindness or health problems reported by their parents. Informed parent consent was obtained before the experiment. Twenty-four infants passed the criterion of completing at least 10 trials in each condition. Six infants were tested but excluded from the final data set because of insufficient number of trials ($n = 4$) or fussiness ($n = 2$). During each lab visit, an infant received both familiarization conditions (familiarized-to-top-heavy and familiarized-to-bottom-heavy) in random order.

3.2. Apparatus and stimuli

Fig. 1 illustrates the three types of stimuli and the flow of the FNP procedure. The stimuli mimicked the three pairs of "top-heavy" and "bottom-heavy" geometric figures (T-shape, 甲-shape, and ⊓-shape) used in Simion et al. (2001). But in the current stimuli, the surrounding white squares were removed because we were concern that the white square against black background might induce high contrast edges and thus it may distract infant's attention to the test display. However in our case, the light-gray cardboard frame that surrounds our monitor display (light-gray cardboard against white background created a small luminance edge that is less distracting) actually serves as a new common reference frame for each pair of the stimuli; this is true for the study as well as for the test pairs. We used the same *viewer-center frame of reference* to define top-heavy versus bottom-heavy configuration as in Simion et al. (2002, p. 429–430). The "top-heavy" geometric patterns contain more high-contrast elements (i.e., the black squares) in the upper part (above the *midline of the whole display*[1]); in contrast, the "bottom-heavy" geometric patterns contain more elements in the lower part (below the midline). Each stimulus contained five black squares (3×3 cm^2), with a distance of 2 cm between each squares. The stimuli were always presented in pairs and side-by-side on a light-gray background. The distance from the center of the fixation and the center of one side of stimulus was 13.75 cm. An Asus (AS-D360) personal computer with 22″ LCD monitor and E-Prime (professional 2.0) software were used to run the experiment. The monitor was framed by light-gray cardboard to match the white background. Infant subject was held by a well-trained observer in front of the monitor at a distance of about 30 cm. The observer's view to the monitor was blocked by a piece of cardboard protruding out of the frame. The observer can see the infant's full face view through an online video-monitor system.

3.3. Procedure

A multiple discrete-trial technique, the forced-choice novelty preference (FNP) procedure (for more detail, see Chien, 2003) was used to test whether infants show significant novelty preference after familiarization. The main advantage of the FNP procedure is to allow for repeated measurement for the same pair of stimuli, and thus yielding enough statistical power to analyze individual infant's data as well as the group means. Each FNP trial contains two phases. In the study phase, a black fixation cross in the center of the screen was first appeared to attract infant's attention. When the infant was judged to attend to the screen, two identical geometric figures (either "top-heavy" or "bottom-heavy") appeared for as long as infants were judged to look away from the monitor display. Based on our experience, in the first few trials, infants tend to look back and forth frequently between the two identical stimuli (showing a sign for encoding the familiarization stimuli), and the duration of the study phase usually extended about 6–10 s until they looked away. As the experiment went on, infants still paid attention to the stimuli pair in study phase of each trial, however, their overall looking time would drop to about 3–5 s on average for the remaining trials. In the test phase, infants were presented with two stimuli where one was the same as in the familiarization and the other was a novel one that was rotated

[1] When using the number of blocks above versus below the (imaginary) horizontal midline to define top-heavy versus bottom-heavy configuration, a small discrepancy on the strength of top-heaviness arises. Using this metric, the so-called 3-unit T-shape actually has a 3.5/1.5 top- versus bottom-heaviness while the 4-unit -shape has a 3/2(i.e. $1 + 2 \times 0.5$) value, which is inconsistent with the description in Simion et al. (2002). However, to be able to compare with their results on the same scale, we followed the original "inexact" top-heaviness metrics (i.e., T-shape < -shape < -shape).

180°. The observer judged the infant's overall looking behavior through the online video-monitor system, and made forced-choice responses by foot pads (left or right). Because the current stimuli were considered relatively simple (c.f. as compared to pictures of faces or scenery), except that infants might look longer at the test stimuli in the very first few trials, on average, the infant's looking time to either test stimuli was about 1–3 s. Therefore, the observer could normally obtain sufficient looking signals to make a novelty preference judgment in the test phase in about 3–5 s. In one lab visit, each infant received both the "familiarized-to-top-heavy" and "familiarized-to-bottom-heavy" conditions in random order. There were 24 trials in each familiarization condition (3 pairs of geometric figures × 2 location combinations × 4 repetitions) presented in randomized order. For those infants who passed the data inclusion criteria, the average numbers of trials obtained for the "familiarized-to-top-heavy" and "familiarized-to-bottom-heavy" conditions were 22.9 and 23.2, respectively.

4. Results

The dependent variable in this study was the "observer's percent correct" which was scored as the percentage of the trials that the observer correctly judged the locations of the novel stimuli in the test phase basing on the infant's overall looking behavior. By definition, the novel stimuli were the figures with top-heavy configuration in the familiarized-to-bottom-heavy condition, whereas the novel stimuli were the figures with bottom-heavy configuration in the familiarized-to-top-heavy condition. If infants of this age range can readily discriminate the differences between top-heavy and bottom-heavy configurations, we expect to obtain greater-than-chance OPC (significant novelty preferences) for all three types of figures across familiarization conditions. This is exactly what we found. Clearly, the observer's percent correct score was significantly greater than chance for the top-heavy patterns in the familiarized-to-bottom-heavy condition for all three figures and three ages (mean = .61, $t(23) = 4.65$, $p < .001$). Moreover, in the familiarized-to-top-heavy condition, the observer's percent correct score for the bottom-heavy patterns was significantly greater than chance (mean = .59, $t(23) = 3.88$, $p < .001$). In terms of comparing the magnitudes of the OPC scores for the two familiarization conditions, we found no significant difference between the two.

In addition, as infants completed multiple repeated FNP trials in each familiarization condition, we did a split-halve analysis to test whether the infant's novelty preference remained at the same level of significance for the first half (the 1st to the 12th trials) and the second half of the data (the 13th to the 24th trials). The results were reassuring; the mean scores for the first versus the second half were .57 and .60 in the familiarization-to-bottom-heavy condition, and were .59 versus .62 in the familiarization-to-top-heavy condition, respectively. In other words, there was no significant difference in the split-halve analysis, showing that the level of novelty preference remained fairly constant through out the experimental period.

Fig. 2 illustrates the observer's percent correct scores separately for the three age groups across figure types. For the youngest group (<=13 wks), the mean OPC scores were .58 ($t(7) = 1.79$, $p = .055$, marginal significant) and .63 ($t(7) = 2.40$, $p = .011$) for the familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions, respectively; the difference between the two was not significant. For infants aged between 13 and 18 wks, the mean OPC scores were .59 ($t(7) = 2.11$, $p = .034$) and .61 ($t(7) = 3.55$, $p = .004$) for the familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions, respectively; there was no difference between the two. For infants aged between 18 and 24 wks, the mean OPC scores were .59 ($t(7) = 2.27$, $p = .026$) and .60 ($t(7) = 2.05$, $p = .037$) for the familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions, respectively; and there was no difference between the two.

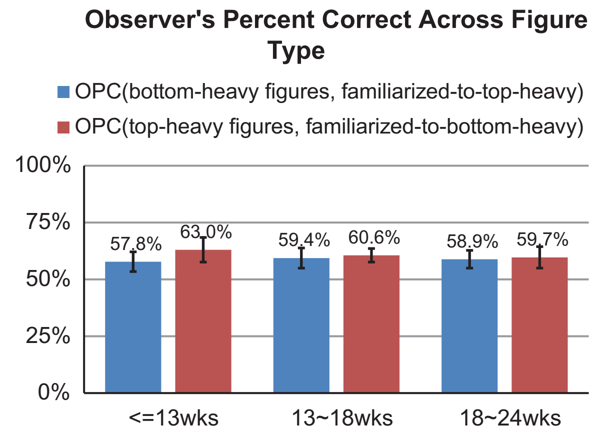

Fig. 2. The mean observer's percent correct scores for the three age groups across figure types. The abscissa represents the three age groups (<=13 wks, 13–18 wks, 18–24 wks). The ordinate depicts the observer's percent correct scores for correctly judging the locations of the novel stimulus over repeated trials. Error bars represent the standard errors of the group means. The results indicate significant novelty effects for the novel stimuli in both the familiarized-to-top-heavy and the familiarized-to-bottom-heavy conditions and for across figure types.

In addition to the comparisons between group means, we did a correlation analysis on the individual infant's delta OPC score and their age. This is to further illustrate whether there is an intrinsic bias for either the top-heavy or the bottom-heavy one in relation to their age. The delta OPC score is the difference score between the familiarized-to-bottom-heavy and familiarized-to-top-heavy conditions with the former minus the latter. If infants have an intrinsic bias towards the top-heavy configuration, we expected to see positive delta OPC scores; on the other hand, a negative score means a preference for the bottom-heavy one. Zero means no preference. Fig. 3 illustrates the scatter plot for 24 infant's delta OPC score and their ages (in weeks) across figure types. As shown

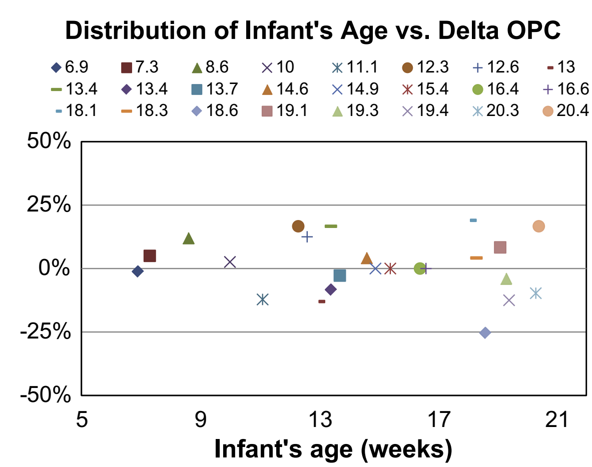

Fig. 3. The scatter plot between infant's delta OPC for the two familiarization conditions and their age across figure types. The abscissa represents infant's age in weeks. The ordinate depicts the difference in the observer's percent correct scores between the familiarized-to-bottom-heavy and the familiarized-to-top-heavy conditions with the former minus the latter. A positive delta OPC score means an intrinsic bias for the top-heavy configuration, while a negative delta OPC score means an intrinsic bias for the bottom-heavy one. Zero means no preference. Despite some individual variability, the overall results indicate that there is no consistent bias for either configuration in this age range.

in Fig. 3, among the 24 infants, 11 of them have a delta OPC that is close to zero (within ±0.05). Although there are individual variability showing non-zero delta OPC scores, the signs of the value are fairly equally distributed along the zero line; that is, seven out o 24 showed a positive score while the remaining six infants showed a negative score. The mean delta score is about 0.01, which was not significant from zero. Thus, no consistent configuration bias can be drawn. Finally, the correlation between infant's age and the delta OPC is about −.135 ($p > .05$), which was not significant from zero. This again suggested no consistent correlation between infant's intrinsic preference and age.

To summarize, we found significant and equal preferences for the novel patterns in all age groups and in both familiarization conditions, indicating that infants of this age range can reliable discriminate between the top-heavy and bottom-heavy configurations. In addition, it seemed that there is no intrinsic bias for the top-heavy configuration as the magnitudes of OPC were about equal in both familiarization conditions for each age group.

Fig. 4 illustrates the observer's percent correct scores separately for the three types of figures across age. For the T-shape figures, the mean OPC scores were .55 ($t(23) = 1.48$, $p = .07$, marginal significant) and .64 ($t(23) = 2.72$, $p = .006$) for the familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions, respectively; and the difference between the two was not significant. For the 甲-shape figures, the mean OPC scores were .62 ($t(23) = 3.44$, $p = .001$) and .59 ($t(23) = 2.42$, $p = .012$) for the familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions, respectively; and there was no difference between the two. For the ⊓-shape figures, the mean OPC scores were .58 ($t(23) = 2.56$, $p = .009$) and .60 ($t(23) = 2.63$, $p = .007$) for the familiarized-to-top-heavy and familiarized-to-bottom-heavy conditions, respectively; and there was no difference between the two. Thus, significant and about equal preferences for the novel patterns were found in all figure types and in both familiarization conditions, indicating reliable discriminability between the top-heavy and bottom-heavy configurations and there is no intrinsic bias for the top-heavy configuration as the magnitudes of OPC were about equal in both familiarization conditions. This pattern of results was also supported by a three-way mixed ANOVA (one between-subject factor: age group (3 levels); two within-subject factors: figures (3 levels), familiarization type (2 levels)). Neither the main effects nor the interaction terms reached statistical significance.

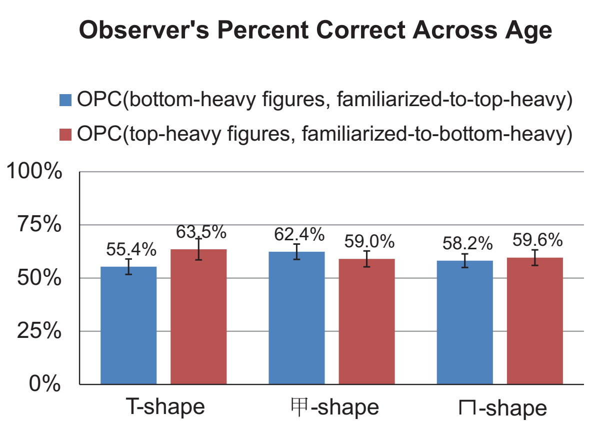

Fig. 4. The mean observer's percent correct scores for the three figure types across age groups. The abssisa represents the types of figures (T-shape, 甲-shape, ⊓-shape). The ordinate dipicts the observer's percent correct scores for correctly judging the locations of the novel stimulus over repeated trials. Error bars represent the standard errors of the group means. The results indicate significant and about equal novelty effects for the novel stimuli in the familiarized-to-top-heavy and the familiarized-to-bottom-heavy conditions and for all three figure types.

5. Discussions

Using the FNP technique, we found significant and about equal novelty effects in all three figure types and in both familiarization conditions across age. This suggests that infants aged between 2 and 4.5 months can reliably detect the differences between the top-heavy and bottom-heavy configurations and their looking preferences seemed to be predominantly controlled by detectable differences between the top-heavy and bottom-heavy configurations, rather than by an intrinsic preference for the top-heavy ones. The finding that young infants did not show reliable looking preference for top-heavy configuration is consistent with a few recent studies. For example, Islam et al. (2010) tested 4- to 10-month-old infants with photographs of artifacts (i.e., light switch, shovel, cheese grater, etc.) in which the configuration of elements in the photographs had a top-heavy and face-like appearance. On each trial, the upright (top-heavy) and the upside-down (bottom-heavy) versions of the same image were presented side-by-side. The results showed that infants did not prefer the upright face-like images over the same images upside-down, suggesting that they did not perceive the pictures as face-like, nor did they prefer top-heavy configuration.

Furthermore, in a separate study, we (Chien & Hsu, 2010) used an eye tracker (Tobii T60) to directly measure if there is spontaneous preference for the "top-heavy" configuration in infants aged between 2 and 5 months (mean age = 20 wks) and for adults as a comparison group. Three classes of stimuli were used; the "top-heavy" and "bottom-heavy" geometric patterns used in Simion et al. (2002), schematic face-like figures used in Turati et al. (2002), and the photographed faces used in Macchi Cassia et al. (2004). Each infant and adult viewed all three classes of stimuli, presented in pairs of top-heavy versus bottom-heavy configurations. Using the area of interest (AOI) analyses on fixation duration and counts, we then computed the top-heavy bias index (between −1 and +1) for each stimulus pair and for each infant and adult, in which a value of +1 means a strong bias for top-heavy patterns and −1 means a strong bias for bottom-heavy ones. We found that the mean values of top-heavy bias indices for geometric and schematic face-like patterns were close to zero in both infants and adults. Taken together, our findings suggested that the "top-heavy" configuration bias, which is present in newborns, does not seem to be functioning at the age of 2 months. We will now turn to compare between our results and that of Turati et al. (2005).

5.1. Comparing the results of Experiment 2 in Turati et al. (2005)

At the first glance, our results seemed consistent with the results of Experiment 2 in Turati et al. (2005). However, the present study made a distinct claim that departs from Turati et al's (2005) suggestion. In their paper, they stated that "overall, evidence obtained in Experiment 2 leads us to conclude that a tendency to explore more extensively configurations that display more patterning in the upper part is still present, although weaker, in 3-month-olds" (p. 266).

We disagree on this. As we illustrated earlier that if the salience of top-heaviness (or up-down asymmetry) is positively correlated with the strength of the 'top-heavy' configuration bias (i.e., ⊓-shape > 甲-shape > T-shape) as suggested by Turati et al. (2005), we would expect to find the following pattern of results: In the *familiarized-to-bottom-heavy* condition, the OPC for the top-heavy ⊓-shape figure shall be the highest, followed by that for the 甲-shape figure, and the OPC for T-shape figure shall be the lowest among the three. The reversed pattern shall be found in the *familiarized-to-top-heavy* condition. Namely, the OPC for the bottom-heavy ⊓-shape figure shall be the lowest, followed by that for the 田-shape figure, and the OPC for bottom-heavy T-shape figure shall be the highest among the three. However, we did not find any differences among the three figure types at all. Thus, our results support the notion that the top-heavy configuration bias has vanished as young as 2 months of age. We are more inclined to conclude that the intrinsic top-heavy configuration bias is absent at this age, rather than still present, although weak. Nevertheless, at a deeper level, our findings do not totally disagree with the results by Simion et al. (2002) and Turati et al. (2005); because what we provided here is that the neonatal 'top-heavy' configuration bias found previously may be a extremely short-lived phenomenon.

5.2. A note on the FNP technique

In the past few years, the multiple discrete-trial FNP technique (Chien et al., 2003) and its variant version have been successfully used to investigate infant's basic discriminability for suprathreshold stimuli as well as infant's subjective perceptual similarity. These included studies with infant's color preference (Civan et al., 2005), color induction phenomenon such as simultaneous color contrast (Pereverzeva & Teller, 2005, 2009), lightness induction with a change in the surround luminance (Chien, Teller, & Palmer, 2005; Chien et al. 2003), and the development of lightness constancy (Chien, Bronson-Castain, Teller, & Palmer, 2006). As compared to other traditional methods studying infant's perceptual development such as *habituation* or *familiarization* procedures that take infant's fixation time as the dependent variable, the unique advantage of the forced-choice testing method lies in its capacity to obtain sufficiently high number of repeated trials in an individual infant, thus allowing for quantitative estimation of *individual* infant's novelty preference. This is typically unavailable with the traditional methods that reply on group means.

What might be the basis of the FNP technique to work? We consider that FNP can be regarded as the infant's version of the "change-detection" paradigm in the adult psychophysical studies, where the length of delay between the study and the test phase is often within 3 s in our case. To put it in another way, we would phrase that FNP technique has to rest on infant's short-term memory representation, which is accountable because several studies have shown that infants have visual short-term memory capacity (Blaser, Kaldy, & Biondi, 2010; Kaldy & Leslie, 2005; Ross-Sheehy, Oakes, & Luck, 2003). In our view, it is likely that the infant's looking preference for the "novel" stimulus in the test phase is elicited by a "detectable discrepancy" between the (remembered) stimulus representation in the study phase, and thus FNP is well-suited for studying infant's perceptual discriminability. However, we would like to emphasize that FNP is suited for discrimination, but not limited to it. FNP can be further applied to study perceptual categorization or generalization in which both test stimuli can be novel in its own definition.

6. Conclusion

In conclusion, the present study suggests that infants aged between 2 and 4.5 months can reliably detect the differences between the top-heavy and bottom-heavy figures, and their looking preferences are predominantly controlled by detectable differences between the top-heavy and bottom-heavy configurations, rather than by an intrinsic preference for the top-heavy ones. Thus, we support the notion that the non-specific innate bias for "top-heavy" configuration seems to vanish quickly at about 2 months of age. From this age on, infants' preference for faces would reflect a fast learning process specifically tuned to the representations of faces, and not the top-heavy configuration.

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